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# *Environment Energy Assessment of Trips (EEAT): An updated approach to assess the environmental impacts of urban mobility The case of Lille Region*

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## *Abstract:*

This paper deals with sustainable mobility in an urban context. We investigate the assessment of the impacts of the evolution of travel behaviour (travelled distance and modal choice) in terms of energy consumption and greenhouse gases (GHG) emissions at the local level. Indeed, today, the control of exhausts generated by the mobility within the urban areas is at the core of the environmental policies and the stabilisation of GHG emissions is one of the main goals of 'sustainable development'. To face this challenge in the transport sector, the national government and local authorities need a better understanding of the link between urban development choices, the operation of the different modes of transport systems, and residents and non residents' attitude, and mobility patterns at the local level.

For this purpose, INRETS defined a new approach enabling to estimate and relate the inventory of mobility-related energy consumption and pollutant emissions to the individual behaviours, as they are decribed in the local mobility surveys.

The "Environment Energy Budget of Trips" [EEBT] (Hivert § al., 1997, 2003)[2] is based on trips made by individual on a casual weekday within his regions of residence and provides spatialized energy consumption and GHG emissions assessment of it. It includes at the disaggregated level:

- on the one hand, a "daily Transport-related energy Budget" (TEB), which gives the sum of energy consumption related to the daily mobility of each individual,
- on the other hand, several "daily Pollutant Emissions Budgets" (PEB) accounting for the carbon dioxide and each of the regulated pollutants (carbon

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[2] Hivert L., Gallez C. and Polacchini A.R. (1997) 'Environment energy budget of trips (EEBT): a new approach to assess the environmental impacts of urban mobility', Paper presented to 4e Colloque international "Transport and air pollution", Avignon, 9-13 june 1997, 8 pages, published in "International Journal of Vehicle Design, The Journal of Vehicle Engineering and Components", 20(1-4), 1998, Inderscience Enterprises Ltd, GB, pp 326-334. Hivert L., Noppe J. and Quételard B. (2003) 'Environment energy assessment of trips in the Lille urban area'. Paper presented at the TILT Conference, GRRT 20th birthday, Lille (France), December 2003 (proceedings pp. 83-94).

monoxide, hydrocarbons, nitrogen oxides and particles matters) emitted during the daily individual trips.

On the contrary with more traditional inventory approach, the main goal of the EEBT is not to only determine the overall pollutant emissions generated by the traffic and to draw the inventory of pollutant emissions with a focus on the networks. Its purpose is rather to refer the environmental impacts of the mobility to the population behaviours within a given urban area and to simulate the variations of these impacts as a result of changing individual behaviour depending on socio-economic and demographic determinants.

Recently, INRETS and CETE Nord-Picardie have updated the method in order to take into account all the daily mobilities, including resident, transit and exchange traffics, for both passengers and freight. This expanded method is named "Mobility Environmental Diagnosis" (MED).

The assessment method is applied to the case of Lille, the largest Metropolitan Urban Area of in the Northern part of France. We adopt a longitudinal perspective over the 1990s, based on the 1987/1998/2006 Household Travel Surveys, showing then the salient dynamic patterns. The paper is two-fold. On the one hand, we develop an analysis of the environmental balance of the residents of the area, computing daily energy and air pollutants budgets over two decades. We compute then EEBT for the Lille residents in a context of a slight fall of mobility. On the other hand, the original initial method is enriched in order to take into account all types of traffics (as to say residents and non-residents flows and freight flows within the Lille Region but also crossing the Region); this updated methodology is applied to provide a 2006 enlarged assessment.

Concerning the results in perspective, we point out that the decrease of energy consumption and CO2 emissions related to transport activities has a double impact both in change in travel behaviour but also in the renewal of the car fleet integrating new technological improvements (section 2). But the enlargement of the analysis balances these results. Indeed, we show that the reduction of EEBT for the residents is not compensating the huge growth of CO2 emissions due the important development over the two decades of the flows of non-residents and of freight external flows (section 3). This situation is the result of the overwhelming share of haulage and road passengers' traffics (with more longer distance trips, notably due to urban sprawl) also observed in other France and Europe metropolitan areas, but especially here in a strategic region being at the cross-road of the different business centres of Europe.

## 2. Environmental balance of the inhabitants of Lille Region: stabilisation of GHG emissions

### 21 Methodology

A. Environmental assessment of air pollution of the transport sector

The Mobility Environmental Diagnosis (MED) aims to estimate the energy consumption (in goe or grams oil equivalent with one unique unit which is 1 liter of gasoline = 750 goe, 1 liter of diesel = 840 goe), and the emissions of Air Regulated Pollutants and Greenhouse Gases directly related to transportation and traffics.

**> Greenhouse Gases (GHG):**
Though the GHGs have no direct and local health impact, they contribute to the mid-and long-term climate change. The current and/or probable future consequences of Climate change are: modification of average earth surface temperatures and level of precipitations more or less important according to the regions, increasing frequency of extreme weather events (tempests, hurricanes, and heatwave), rise in the level of oceans, modification of landscapes, and reduction of biodiversity.

Carbon dioxide ($CO_2$) accounts for 95 % of the GHG emissions by the transport sector. Our method of diagnosis, the MED, computes the contributions of transportation by a unique indicator, the $CO_2$ equivalent ($eqCO_2$), which «adds up» the contributions of the different GHGs by using an equivalence defined in terms of the century global warming potential of each atmospheric gas. For example, the emission of one ton of methane ($CH_4$) contributes 23 times more than one ton of carbon dioxide to global warming. This rate is of 130 in the case of nitrogen protoxide ($N_2O$), third and last GHG taken into consideration in this indicator.

**> Local air pollutants:**
These gases (when present in the air) contribute to the worsening of air quality at the scale of urban areas (downtowns, suburbs and peri-urban areas). Their harmfulness (in high concentrations) has been acknowledged for many years now (Several epidemiological studies dealing with the health effects of air pollution from automobiles):
- carbon monoxide (CO), is a poison gas (suffocation) which, at high concentrations, settles in haemoglobin, and prevents the transport of oxygen by blood;
- nitrogen oxids (NOX) are mainly composed of nitrogen monoxid (NO), which generates cyanosis and of nitrogen dioxid ($NO_2$), which harms respiratory tracts and can generate severe poisoning in case of exposure to high concentrations;
- hydrocarbons or volatile organic components (VOC)[3], very worrying from the health point of view, gather many pollutants as aldehides, benzene, toluene, etc. several of them being carcinogenic;
- total particles hanging in the air (pm) group together very heterogeneous suspended substances (aerosols, smokes, ashes, pollen, smog…), without any consideration to their chemical composition and nature. As the particles emitted by diesel engines, the smallest particles can deeply penetrate into the respiratory system[4].

The latest results are used to establish dose-effect relationships, distinguishing:
- The short term, following several days of minimal increases in daily levels of some of these pollutants. Are studied cardiopulmonary mortality, and acute episodes of bronchial asthma attacks, particularly along the known risk groups (infants and young children, elderly, cardiac or respiratory failure);
- And the long-term effects of cumulative effects over a long period, observing the effects of increasing concentrations of annual averages, with the onset of cancers, including lung, and installation of chronic diseases such as bronchitis chronic.

Knowing the exposure of the population, the dose-effect relationships can calculate a number of cases of these diseases due to air pollution. Finally, epidemiological surveillance, in a large number of towns in France and Europe, allows to highlight the (short and long

[3] The term was coined by a Ministerial decision issue the 1rst of March 1993.
[4] Abbey DE , Mills PK , Petersen FF , Beeson WL Long-term ambient concentrations of total suspended particulates and oxidants as related to incidence of chronic disease in California Seventh-Day Adventists. Environ Health Perspect, 94: 43-50 1991

term) health effects of urban air pollution, for wihich around half (decreasing share) is due to road traffic. The risks are "low" at the individual level, but, considering the importance of exposed population size, the numbers of cases related to this pollution are finally significant.

Moreover, CO, NOX and VOC chemically change with solar radiance and produce ozone and other dangerous substances (species) for health and environment. Despite significant decreases in CO and VOC emissions, the concentration of ozone in the atmosphere is regularly increasing. Ozone spreads on large geographical scales and contributes to greenhouse effect.

B. EEAT method to compute energy consumption and air pollution due mobility if residents

The quantities of CO2 emitted by the residents during their trips whithin their urban area are estimated by INRETS, according to our previously developed EEAT method (for this assessment and budgets method, see details in (Hivert et al., 1997), Quételard et al., 2002) and (Hivert, 2007)), using the emissions coefficients recommended at the European level in COPERT III methodology, MEET Project (INRETS et al., 1999).

The "Environment Energy Budget of Trips" is based on trips made by an individual on a casual weekday within his or her region of residence. It includes:

- on the one hand, a "Transport-related Energy Budget" (TEB), which is equivalent to the overall energy consumption resulting from his or her trips ;

- on the other hand, several "Pollutant Emissions Budgets" (PEB), accounting for carbon dioxide and each of the four regulated pollutants (carbon monoxide, hydrocarbons, nitrogen oxides and particulate matters) the total volume of pollutants emitted during those trips.

As opposed to more traditional methods aimed at drawing up an inventory of pollutant emissions from transport activity as observed on the networks, the approach related to the Environment Energy Budget of Trips is not intended to determine the overall pollutant emissions generated by traffic. Its purpose is rather to simulate the variations of energy and environmental impacts of the population mobility within a given urban area as a result of the global change in individual behaviour.

Applying this experimental method to three great French urban regions (Grenoble, Paris, Bordeaux and Lille for two consecutive mobility surveys, 1987 and 1998) led us to outline some conclusive results:

- First, at the disaggregated level, we have confirmed the influence of land use on individual mobility demand and, consequently, on its environmental impacts: for instance, higher densities go with lower Transport Energy-related Budget;

- Second, after answering the question "Who pollutes?", we have tried to answer the question "Where do we pollute ?", by drawing pollutant emissions maps at the local level. Those maps, obtained from trips assignment on the transport network, emphasize the respective weights of the different types of links in concentrating traffic and pollutant emissions with particular attention to the long distances generated form or to the farthest outlying suburbs.

Based on successive household mobility surveys (1987, 1998 and 2006 THS for Lille) describing the daily mobility on a working day, this method determines energy consumption and pollutant emissions (including CO2) at the disaggregated level of each trip (of each individual) described in the survey, with respect to trip length, speed and used modes. For the car trips, the vehicle technological characteristics (fuel type, age and cubic capacity) and cold starts are taken into account, while occupancy rates intervene in estimation for PT trips.

In the initial EEBT method, estimating of the fuel consumption and the pollutant emissions due to the trips within the urban region of residence relies on two distinct statistical sources and is based on the main following assumptions:

- First, it is limited to the mobility of persons: the data collected from local household surveys describe precisely the characteristics of each individual trip made during a casual weekday: travel time, mode(s) used, origin and destination, allow us to reconstitute covered distance and average speed. At the current time, freight movements are excluded from our analysis, due to the lack of data similar to those of the household surveys;

- Unit rates of consumption and pollutant emissions - for carbon dioxide ($CO_2$) and the four regulated pollutants, i.e.: carbon monoxide (CO), hydrocarbons (HC or VOC), nitrogen oxydes (NOx) and the particles (PS) - are taken from European work (MEET Project and Copert III methodology), and notably the empirical measurements carried out by the pollution and energy research Laboratory[5] of INRETS (Joumard and coll. 1990, 1991, 1992). For car driver trips, the unit rates of consumption and pollutant emissions are estimated from relatively complex equations, taking into account, besides the type of fuel, the age and power of the vehicle, the speed of the trip as well as the cold starts. For other motorized modes, unit rates do not depend on the average speed.

- And last, the hypothesis of nullity of energy consumption and pollutant emissions is retained for the passengers of the trips made by car, in the absence of information on the occupation rate of the vehicles. This hypothesis means that the totality of the fuel consumption and the pollutant emissions are allocated to the driver of the vehicle.

## C. Data and Zoning

### *« PDU » zoning for the Lille Metropolitan Area*

The Lille conurbation, with multipolar urban form, is the fourth of France.

The zoning for Lille has been elaborated for the “Urban Mobility Plan”[6]. The territory is structured by:

- two main city centres (only 4% of the total surface), Lille and Roubaix-Tourcoing,
- two zones of suburbs around these poles (respectively 25% and 13% of the total surface for Lille and Roubaix-Tourcoing suburbs; 31% of the population for Lille suburb)

[5] now LTE for “*Laboratoire Transport et Environnement*”, former LEN for “*Laboratoire Energie et Nuisances*”
[6] For *PDU : Plan de Déplacements Urbains*, in French

- and a peri-urban zone (55% of the surface for 17% of the population).

These 5 PDU areas, also used for the presentation of our MED results, include the 57 zones of the THS (household survey).

The Mobility Environmental Diagnosis made for that current research covers the territory of the Lille urban community (LMCU for *Lille Métropole Communauté urbaine*, established in 1967), which corresponds to the urban transport perimeter of the Lille built-up area.

In 2006, the LMCU counts 85 districts for an area of 611.45 $km^2$ and a total population of 1 107 861 inhabitants. The main towns of this territory are:

- Lille : 226 014 inhabitants
- Roubaix : 97 952 inhabitants
- Tourcoing : 92 357 inhabitants
- Villeneuve d'Ascq : 61 151 inhabitants

Two urban poles structure this territory: the main one being Lille, and a secondary one, Armentières, with 24 836 inhabitants.

### *LMCU Household Travel Survey*

As the surveys carried on in 1987 and in 1998, the 2006 survey was conducted according to the national methodology of the «travel households survey[7] » defined by the CERTU (Centre d'Études sur les Réseaux, les Transports, l'Urbanisme et les constructions publiques) [CERTU, 1998 § 2008].

But, the 2006 edition referred to the « updated » THS methodology, as to say:

- Specially trained pollsters carry out Interviews at the home of the surveyed individuals;
- One or two persons over 5 years old, living in the place of residence, are interviewed (only one person if the size of the household is one or two persons, and two persons when the size of the household is over two persons), this latter aspect being the peculiar characteristic of the methodological updating of the THS. [8] ;
- All the trips made the previous day by the interviewee are listed and detailed in all their characteristics.

Indeed, these characteristics include purpose at destination, modal choice[9], origin and destination zones, departure and arrival time. All modes are taken into account including walking.

[7] For EMD : *enquêtes ménages déplacements*, in French
[8] This methodological point is of importance; in particular this updated method does not allow the complete and exhaustive sum (distance-budget, time-budget, energy consumption and emissions) for all the members of the household: the energy and emissions budgets computed with the EEBT are then done only for individual and not at the household level.
[9] In the case of individual modes, the description of the fleet owned by the households allows.to assign the technical characteristics of the vehicle to the trip.

This precise picture of daily mobility in the urban area, obtained with the last edition of the THS, has to be compared to the previous ones in order to catch mobility patterns (and behaviours) changes overtime.

For the 2006 edition, between January and June, 8 990 inhabitants were selected to be representative of the population of the 85 districts of LMCU and were interviewed at their home about their "yesterday" trips.

The selected households were stemmed from:

- A random draw, on 57 geographical zones shaping the Lille Urban Community, in the lists of place of residence (housing) established by the Tax Administration[10];
- A sample of 41 student households living in residence halls.

All in all, 36 244 trips were registered (see below the descriptive scheme of the sampling).

[10] For *DGI : Direction Générale des Impôts*, in French

*Description of the sample of the Travel household survey carried on Lille urban community in 2006*

457 353 households

No possible distinction between the "internal" households and the "non internal" households, as a consequence of the updated methodology

1 092 538 individuals
including 1 009 628 over 5 years old

889 590 « internal »individuals 88% | 120 038 « non internal » individuals 12%

4 107 519 trips

3 840 364 « internal » trips 93% | 267 155 « non internal » trips 7%

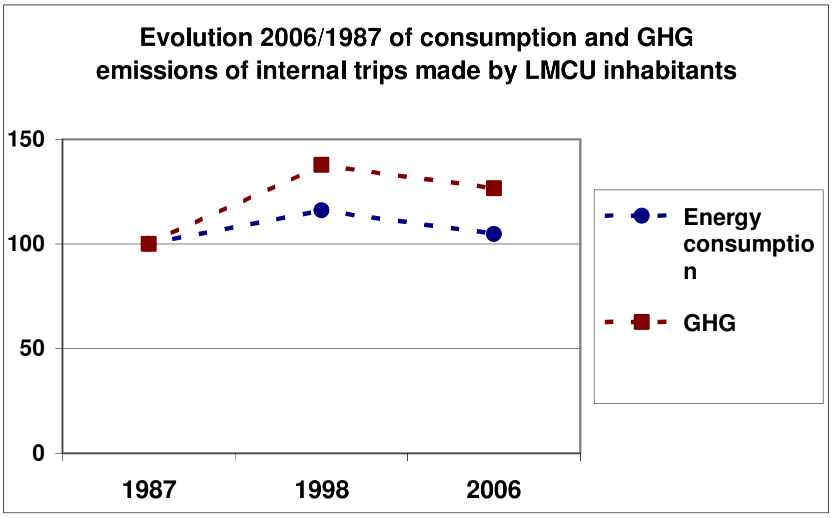
*internal trip means that the origin and the destionation of the trip are within the considered urban area. By extension, internal individuals and internal households correspond to individuals and households, for which all registered trips are internal.*

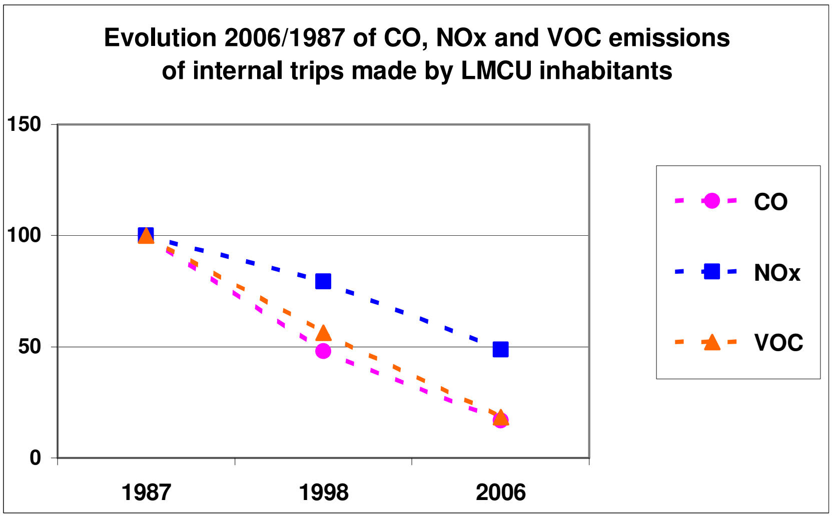
## 22. Results: the (internal) mobility of Lille Region inhabitants and its environmental impacts over two decades

The 2006 THS shows, for the first time since the 1970s, a mobility decrease in terms of number of trips, and a stabilization of road traffic in terms of travelled kilometers by the Lille Urban Community inhabitants. When carrying out the exercise of the "classical" EEAT estimation, we can note that this stabilization is translated in a decrease by 8 % up to 9 % of the energy consumption and GHG emissions as well as in a striking decrease of the emissions of the air local pollutants.

### 221. Less and less polluting trips, but their contribution remains high

The main part of the energy consumption and of the related emissions is the results of car use: the observed changes over the three succssive THS (1987, 1998 and 2006) follow from the one hand the technological improvements and from the other hand the evolutions observed in car use.




The spread of technological improvements (catalytic exhaust pipe, particles filter, etc.), which have led to the decrease in unit consumption and emissions of road vehicles, have been greatly accelerated by the adoption of more and more restricting European Norms. The latters, since the beginning the 1990s, impose more and more lowered (about every four or five years) maximum level of emissions for regulated local pollutants.

| | Euro 1 1993 | Euro 2 1996 | Euro 3 2000 | Euro 4 2005 |
|---|---|---|---|---|
| Oil | maximum emissions (g/km) | | | |
| CO | 2,72 (4,05) | 2,20 (3,28) | 2,30 | 1,00 |
| HC | / | / | 0,20 | 0,10 |
| NOx | / | / | 0,15 | 0,08 |
| COV+NOx | 0,97 | 0,50 | / | / |
| Diesel oil | maximum emissions (g/km) | | | |
| CO | 2,72 | 1,00 | 0,64 | 0,50 |
| NOx | / | / | 0,50 | 0,25 |
| COV+NOx | 0,97 | 0,90 | 0,56 | 0,30 |
| Ps | 0,14 | 0,10 | 0,05 | 0,025 |

These technological advances were not sufficient to balance the sharp increase of internal road traffic between 1987 and 1998. At the opposite, the stabilization of this traffic during the next period between 1998 and 2006 allows to fully enjoy their benefits.

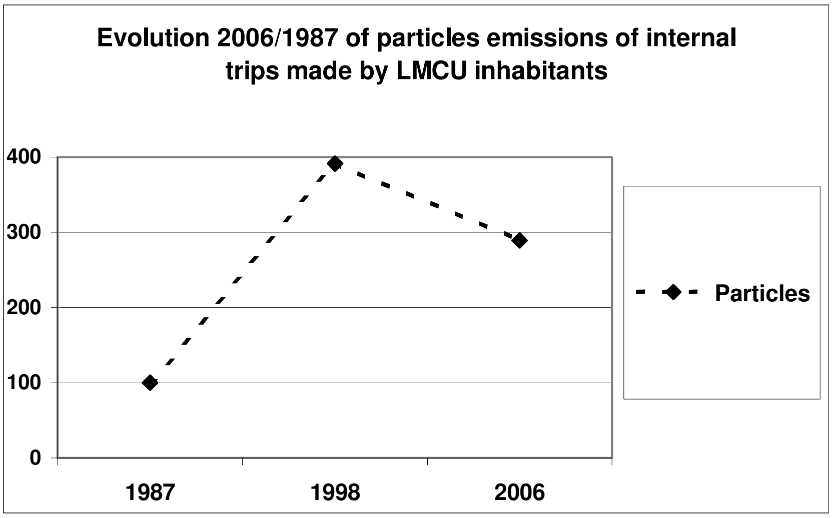
However, if the energy consumption related to internal trips made by car by LMCU inhabitants decreased by 10% between 1998 and 2006, it remains in 2006 5% over the 1987 level.

The GHG emissions follow the same trend with a higher growth between 1987 and 1998 (+38 %), time period where the technological improvements of vehicle engines were mainly focused in reducing local air pollutants (NOx, VOC in particular), more than dealing with CO2 concern.

Apart from the particles, the emissions of local air pollutants have strongly decreased, on a continuous trend, for 20 years since 1987: - 50 % for NOx, - 80 % for CO and VOC.

***• The special case of particles***

The specificity of particles emissions is the following: in the 1987-1998 period, these emissions were multiplied by 4, as the result of an intense «dieselization » of the car fleet (from 10 % up to 34 % of the whole fleet at the National level and from 7 % up to 33 % in the Lille region case). But in the next period, between 1998 and 2006, they decreased by 25 %, thanks to particles filter, while the share of diesel car on the total fleet was still increasing. Indeed, from 1/15 in 1987, this share was of 1/3 in 1998 and almost 1/2 in 2006.
Observing the new vehicle market in Europe, we notice that diesel seems no longer to be a 'French exception' since the early 2000s: the share of Diesel among new vehicles market becomes higher in Austria, Belgium and Luxembourg than in France, and the average share is growing continuously in Europe since 1998.

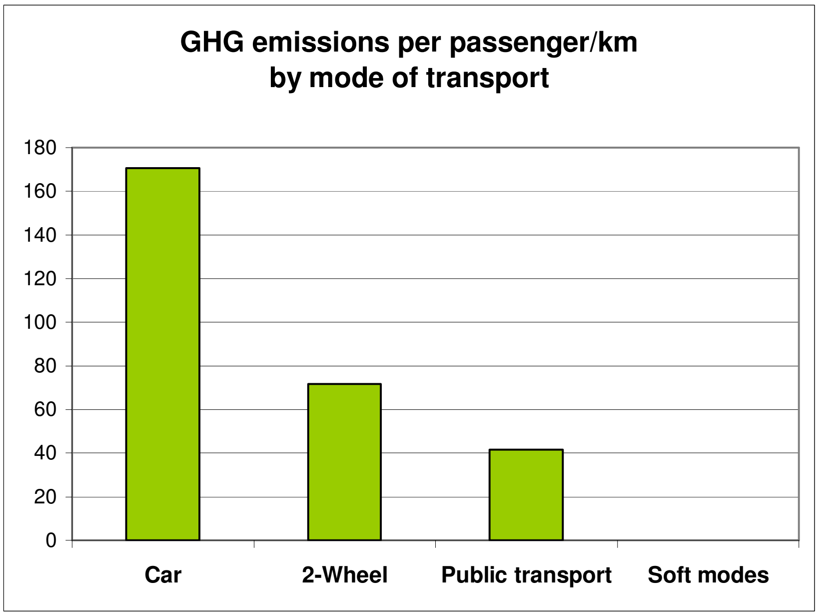


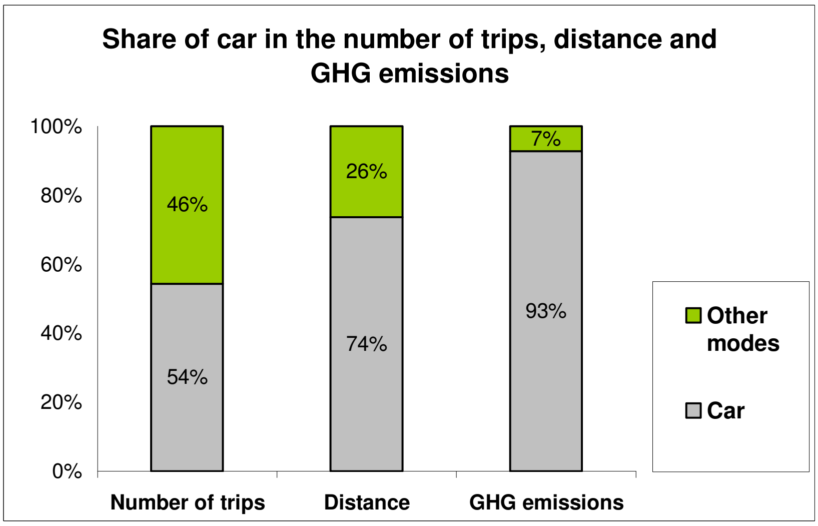

**222. Polluting emissions of the inhabitants internal trips: what are the most determining factors?**

The level and nature of the polluting emissions related to individual trips are dependent of the modal choices, and of the travelled distances in each (consecutive) mode. The kilometers travelled by car are the most determining, whereas trips practices are tightly related to age, level of income, lifecycle and residence locations.

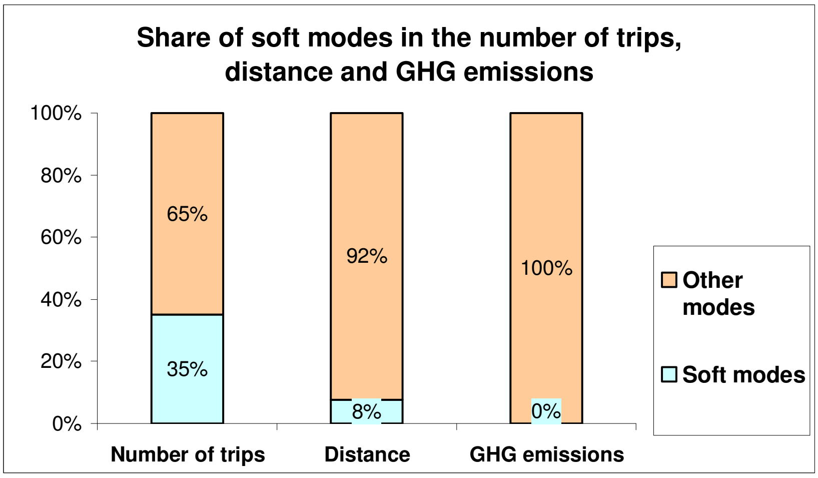
**• A/ Important disparities among modes in terms of contributions to emissions**

Not surprisingly among all the modes, individual road vehicles represent the higher fossil energy consumer and the main supplier of GHG and local air pollutants. In Lille Urban Community, more than half of the trips are done by car (54 % of the total number of trips, in summing drivers and passengers of car), but they also account for 74 % of the travelled distances. Thus, car is identified, in an even much larger proportion, as the main transport mode for energy consumption (92%) and for exhausts with 93 % of the GHG emissions, and even 95 % carbon monoxide emissions.



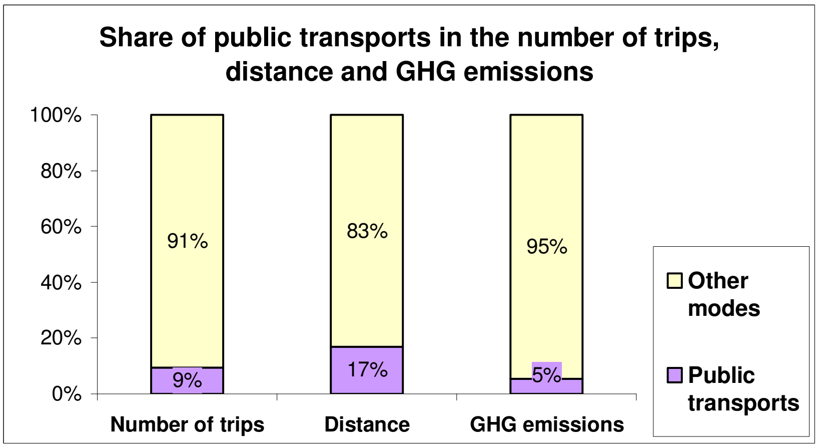




Acknowledging the overwhelming weight of road transport is particularly meaningful when compared to the impact of ‘soft’ (or active) modes as cycling and walking. Their modal share is 35 % of the total number of trips, they account for 8 % of the travelled distances and, of course, they are completely free of GHG and local air pollutants.

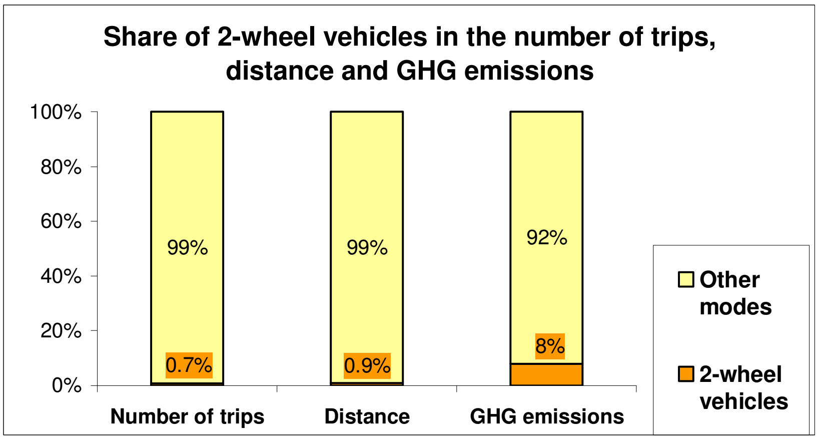



If we consider the unit of the travelled kilometer, car remains the most polluting mode –at the vehicle level- in terms of GHG emissions. But -at the individual level- (taking into account the occupancy rate of the vehicle), and then considering the passenger*km unit, one kilometer travelled by one individual by car emits in average 172 g of GHG.

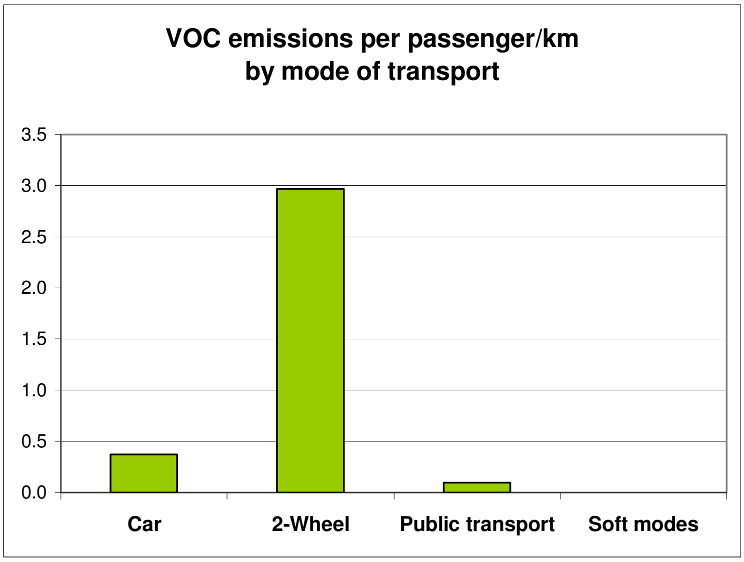
In comparison, the average unit GHG emission factors by passenger*km are finally: 72 g for motorized two-wheel vehicles and 42 g for Public Transit.




But 'Public Transit' is not a homogenous category in terms of energy consumption and emissions. Disparities are noticeable: subway and tramway, running with electrical energy (largely on peut retrouver le % dans mon wctr2007 produced by nuclear power stations in France) have very low level of emissions when the emission factor for bus is of 100 g by passenger*km. All in all, public transit accounts for 5 % of GHG emissions and for 17 % of the travelled distance.

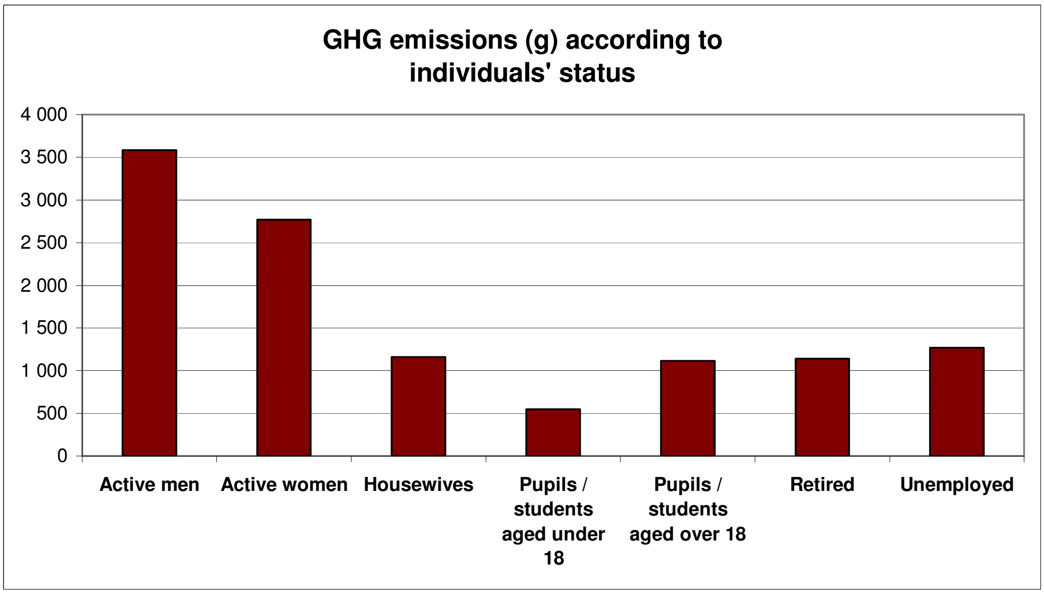


Motorized two-wheel vehicles are a very important source of VOC (volatile organic components) emissions. In spite of their low modal share (only 0,7 % of the total number of trips), bikes, scooters and other mopeds contribute to 8 % of VOC emissions. Finally, one can underline that one kilometer travelled by motorized two-wheel vehicles produces 8 times more VOC than one kilometer travelled by car.




**• B/ Labour force, main contributor to energy consumption and polluting emissions**

Most of the GHG emissions are produced by members of the labour force; and between these active emitters, men are far ahead women (+ 30 %). This huge difference is explained by the fact that men travel longer distances than women and that they more often use car as transport mode than women.




People without work emit three times less GHG than workers. This situation can be explained by the significant contribution of home-to-work commuting trips to the total mobility, and even more to the total emissions, wehter GHG or local air pollutions.

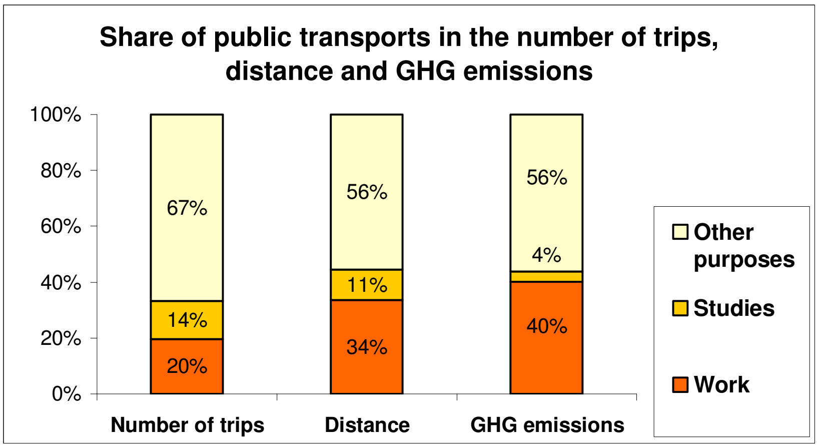
### • C/ Some trip purposes appear predominant

> *Pollution is mainly generated by trips related to work*

Trips related to professional occupation account for :

- 20 % of the total number of trips done by inhabitants,
- but 34 % of travelled distances
- and 40 % of the emissions of GHG, NOx and particles.

Indeed, such trips are longer, and partly for this reason, very more often done by car (80 % against 54 % in average, considering modal share in number of trips).




> *Trips for education purposes contribute less to polluting emissions…*

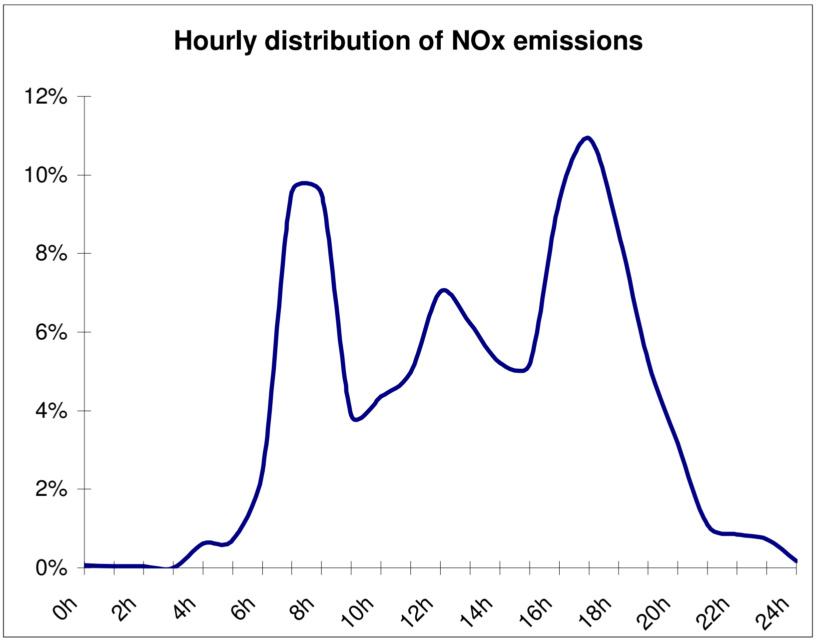
Education as destination purpose (home-to-school trips) represents 14 % of the total number of trips, but only 4 % of GHG emissions, due to shorter travelled distances and massive use of modes like public transport, walking and cycling.

>… *While accompaniment trips are an important (noticeable) source of pollution*

Indeed, accompaniment is often made by car: 15 % of trips, 12 % of travelled distances, and 17 % of GHG emissions. Most of accompaniment trips have school as destination purpose. We can notice that, in perspective between both last THS in 1998 and 2006, the share of this trip purpose seems to have decrease, while the global traffic stabilized.

### • D/ The hourly distribution of pollution is directly related to hourly distributin of road traffic

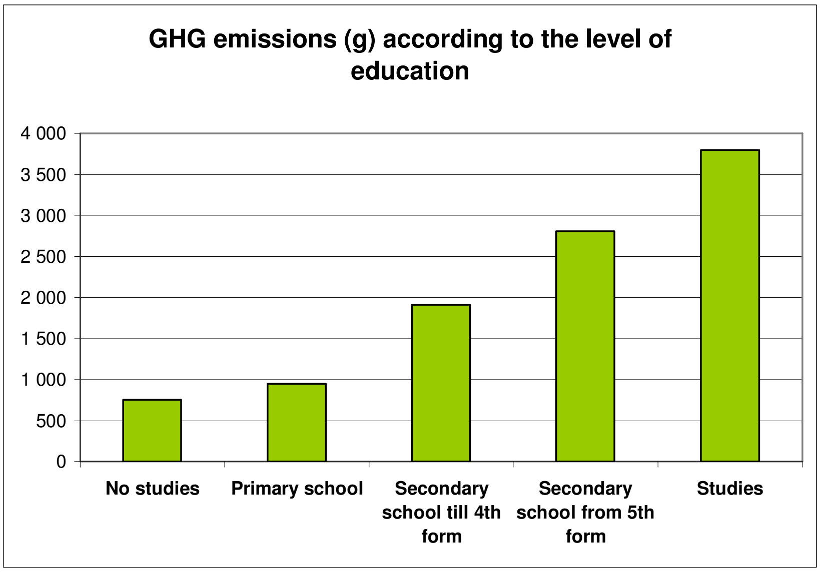
The temporal distribution of emissions strictly follows up the one of trips made by car. Defining this distribution allows to identify the periods of strong emission peaks, preceding periods of high concentrations of nocive local gases in the air. This analysis by hourly schedule confirms the impact of work related trips on traffic peaks and congestion and thereby on the peaks of emissions in the morning and early evening (especially for NOx, main indicator for local pollutants emissions for cars, but one can observe the same trends for other local pollutants).



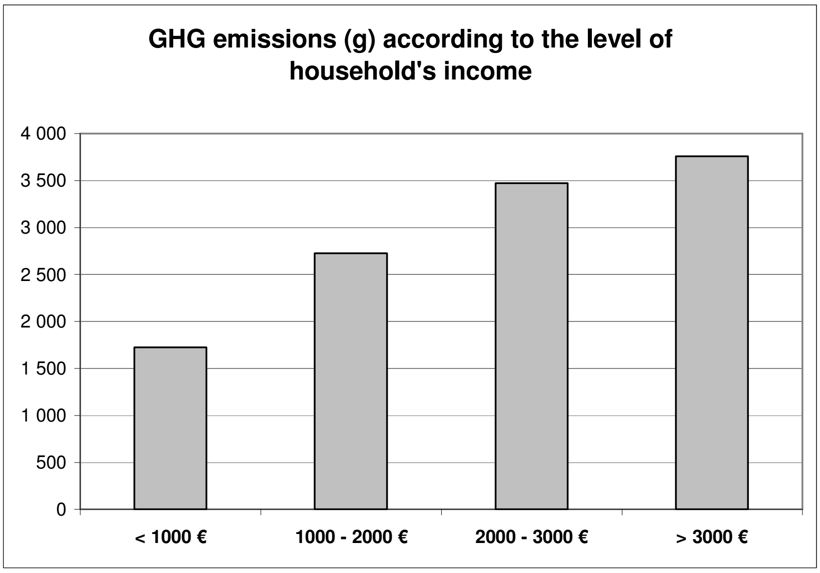

Home-to-work and/or home-to-school distances (and finally schools, works and residents locations) and the accessibility to transport infrastructures strongly matter in order to reduce GHG emissions. Not only density is a silver bullet to sustainable mobility but also diversity of activities over the territory (mixed uses or functional mixity of the spaces), the design of transport infrastructures, the distance to transit and the destination accessibility.

**• E/ The environmental impact of trips is closely related to the individual position in the life cycle**

> Education is a key determinant of mobility patterns and therefore of the level of energy consumption and generated emissions. The relationship between the level of education and the GHG emissions is almost linear: the more graduated the individuals are, the more they use their car and the more they contribute to greenhouse effect and to worsening of air quality. The level of education is certainly related to the age but this correlation has been observed for each age group.



> Income is also a main determinant of travel patterns and then of their environmental impact. Indeed, the daily average quantity of GHG emited by individual has been computed by classes of household income by consumption unit[11] and the result is crystal clear:
Members of households with monthly income are less than 1 000 € per consumption unit, have an average level of GHG emissions of 1700 g by individual. This figure is doubled for households belonging to the second class (monthly income between 2 000 € and 3 000 €). The increase in GHG emissions between the individuals of this second class of income and the individuals belonging to the last class (i.e. with a household monthly income over 3 000 € per consumption unit) is less strong, but a step is still identified.

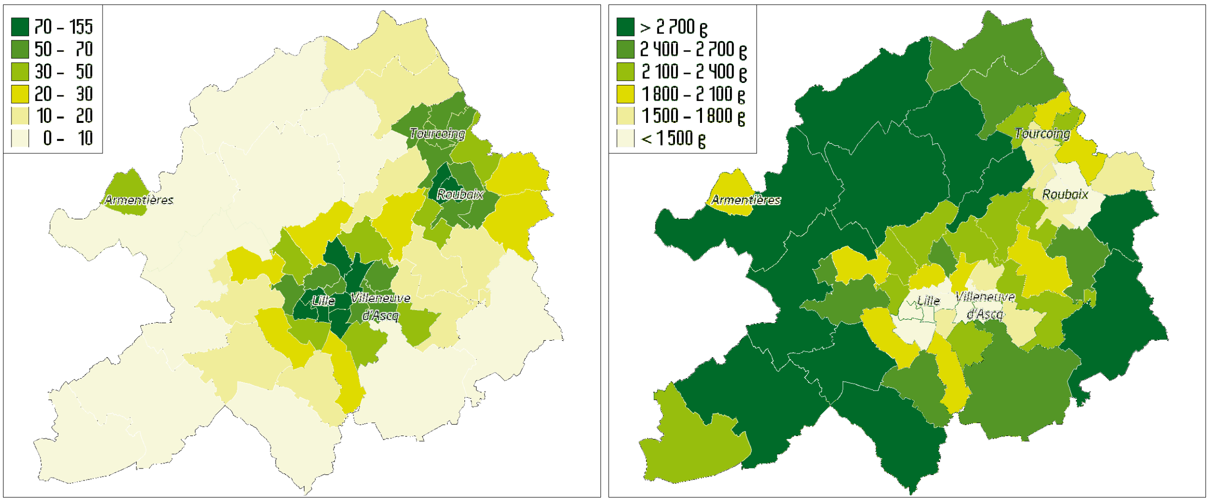



This disaggregation of GHG emissions by class of income confirms the results obtained by disaggregating by education level. There is no surprise in there, since these two variables are obviously highly correlated: the higher the level of education is, the higher the level of income is.
Moreover, Individuals with the highest incomes also have most of the time the highest activity rates and therefore their working activity generates many more trips than the average and these individuals favor faster transport modes and cars in particular. Despite the fact their high level of education allows them a better access to the knowledge and a better awareness on environmental issues, the travel behaviour of the most educated and wealthy individuals and households in the population remains the most energy consuming and pollution generating.

### • F/ Urban sprawl generates longer travelled distances, and then pollution

Rsidential location, density of settlement, and diversity of activities in the same places (housing, work places, shopping, leisure …) are all together key factors in explaining distortions in the level of emissions related to trips of the inhabitants of a geographical zone. The results of Lille are no exception, and confirm different effects already underlined in our previous local case studies (comparing disaggregated estimations), as well as in Newman and Kenworthys' more aggregated works about "cities and automobile dependence".

[11] the classical (or usual) weighting system is used to affect a certain coefficient to each member of the household. By doing so, it allows to compare living standard for same size or differently composed households. On this schedule, the number of individuals is brought back to a number of consumption units (CU) (value: 1 CU for the first adult of the household; 0,5 UC for the other members over 14 years old and 0.3 for the children less that 14).




*Population density (inhabitants/ha) and individual GHG emissions (g) according to households' location of residence.*
Mapping based on the 57 zones of the Lille Urban Community, zoning used for the 2006 LMCU THS.

The number of inhabitants by hectare and the individual emissions of GHG of inhabitants are directly and strongly correlated: the less the territory is densely populated, the higher is the level of individual emissions, and vice versa, as previous EEBT as shown in the past.

> The difficulty to provide an efficient PT supply in outer suburbs and periurban areas

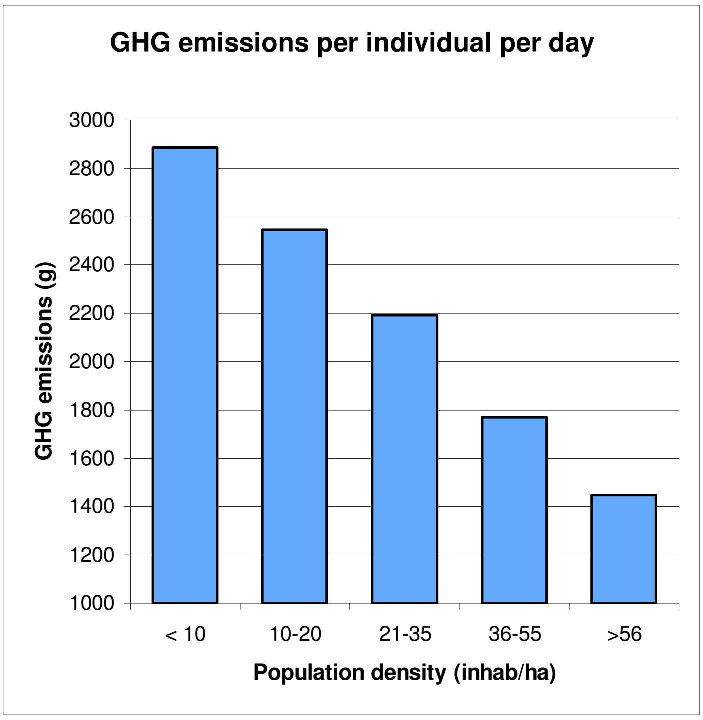
Density and diversity of activities by zone favor proximity trips and thereby cycling and walking, but also promote the development of quite efficient and attractive for all public transit. (Newman P., Kenworthy J., 1989, 1999)

On the opposite, population living in the fringes of the urban area is induced to travel longer distances to reach jobs (often in the city-centre(s)), activities equipments and services, provided by the Urban Community, because all these amenities are generally not close to their home. The cluster of traffic flows related to urban sprawl does not allow the implementation of efficient collective public transit: this explains the huge amount of kilometers travelled by cars by the residents of these zones and the important emissions related to these flows.

> The level of emissions is getting higher as the places of residence are far from downtowns.

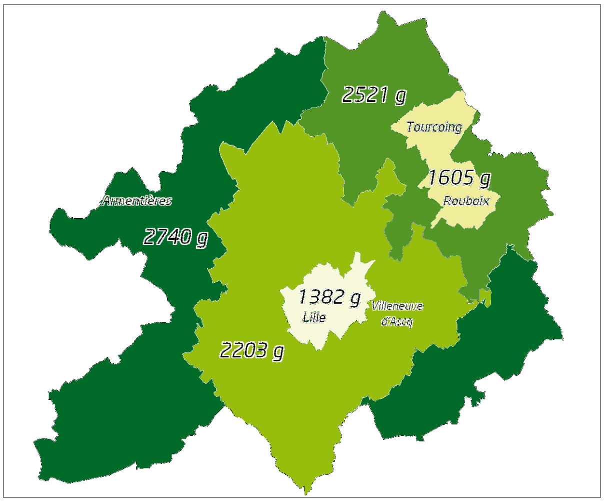
Urban sprawl is inducing an overwhelming use of car as transport mode but more a growing car dependency. The contrasted results for GHG and local air pollutants emissions according to the places of residence, wether they are located in downtowns, in inner suburbs or in the farthest fringes of the urban area are especially speaking for themselves (even in the multipolar specific case of Lille).

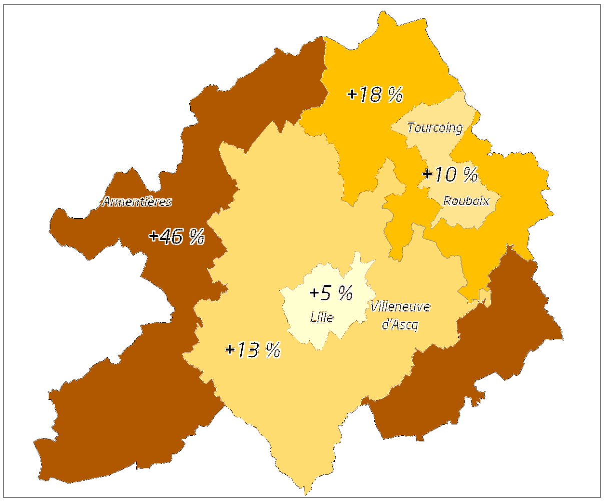
The inhabitants of the zones far away from city centres are those who generate the most polluting trips: when traveling, a inhabitant of periurban areas emits twice as much GHG as compared to an inhabitant of the city of Lille.




In 2006, inhabitants of suburbs and peri-urban zones account for two-third of the LMCU population but for three-quarters of the total transport GHG emissions.

> Growing gaps
This phenomenon has become more and more important as shown by the evolutions of individual GHG emissions since 1987.




Emissions mostly and strongly increased in peri-urban areas over the period (+ 46 %) when the increase was lower in downtowns (+ 10 % in Roubaix/Tourcoing and + 5 % in Lille). The gap in polluting travel behavior between urban and Periurban inhabitants, already existing in 1987, is growing over time.

## 3. Enlargement of the assessment to all traffics (internal, transit and exchange for both passengers and freight) no compensation but contrasted evolutions

### 31. Methodology

The Mobility Environmental Diagnosis (MED) enlarges the EEBT assessment by completing it: the updated methodology accounts for the internal trips of the inhabitants as in the EEBT, but also on the one hand includes the exchange trips of these inhabitants and all individual transit trips, and on the other hand all types of freight traffics (internal, exchange and transit).

As the EEBT, the MED computes energy consumption and emissions for both GHG and local air pollutants. The assessment is still carried at the global geographical level of LMCU, the Urban Community of Lille, and all the trips made outside this area are not taken into account. The geographical boundaries of the environmental assessment are the main difference between the MED and the "territorial Carbon Balance" (Bilan Carbone© in French, according to the methodology developed for the French Environment and Energy Management Agency[12]). The latter only includes internal and exchange trips directly related to running activities on the Urban community Territory – but the total GHG emissions are computed on the overall trip, and by including emissions related to production of the vehicle and fuels.

About internal trips of LMCU inhabitants, MED relies on the previous EEBT methodology of assessment. But for the other types of traffic (passengers trips of transit and exchange, freight traffics), the computation of emissions is done at an aggregate level by multiplying traffic data (travelled kilometers) by unitary emissions coefficients (emissions for one travelled km).

The MED is a global environmental assessment aiming to give a exhaustive picture of energy consumption plus GHG and local air pollutants emissions to be related to the entire transport flows by extending the assessment to all types of transport traffics on the territory of the considered urban area.

Contrary to the «internal» EEBT (allowing detailed analyses), the main goal of the MED is on the one hand to determine the relative weights of the different transport modes and of the different types of traffic in the total emissions assessment, and on the other hand to establish the temporal distribution of their relative contributions to pollution. Thus, the present extended methodology doesn't aim, unlike the EEBT, at identifying and analyzing the different determinant of energy spending related to transport and air pollution, and GHG emissions.

The MED method is not yet officially validated on various local cases and standardized as the EEBT is. The MED relies on a 4-step methodology:

- Inventory of all the traffics to take into account;
- Collection of traffic data;
- Research of the relevant and updated emissions factors
- Computation of energy consumption and emissions.

### 32. Results: striking growth of GHG emissions in Lille Region

[12] For *ADEME : Agencede l'Environnement et de la Maîtrise de l'énergie*, in French

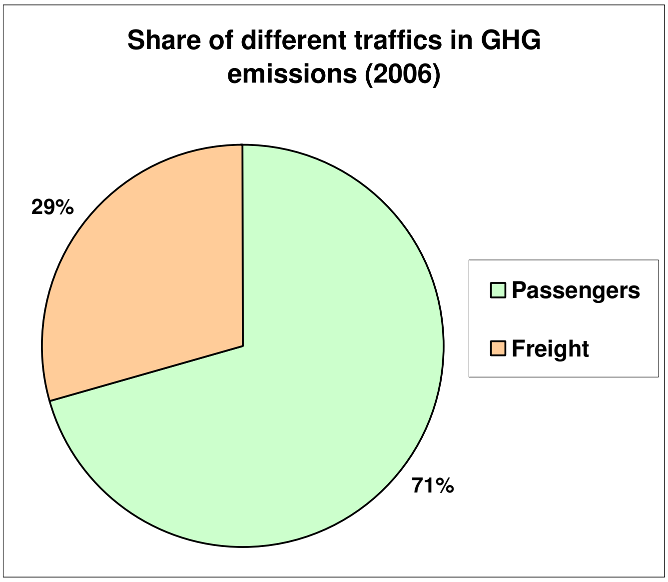
The low increase of CO2 exhausts and of fuel consumption observed for the 1998-2006 period in Lille Metropole marks great disparities in the evolution trends among the different types of traffic. In this way, the balance of passengers is slightly decreasing: it results in a decreasing contribution of the trips made by the inhabitants of the Lille Urban Community, partly compensated by a strong rise of the contribution of passengers exchange and transit flows. The contribution of freight transport to emissions has sharply ridden over the period. And in any case, road traffic remains the main energy consuming mode and the more polluting mode generating, with, for example, more than 90 % of CO2 emissions.

**• A/ More and More GHG emissions are related to transport: an increasing trend**

The Carbon Balance conducted on the territory of LMCU[13] has shown the importance of the transport sector in the GHG emissions on the Lille urban community area (43 % of total).

The MED shows that, all in all, transport sector in 2006 is accountable for around 4,430 tons of GHG emissions by average working day. This represents a slight increase by 5 % compared to 1998.

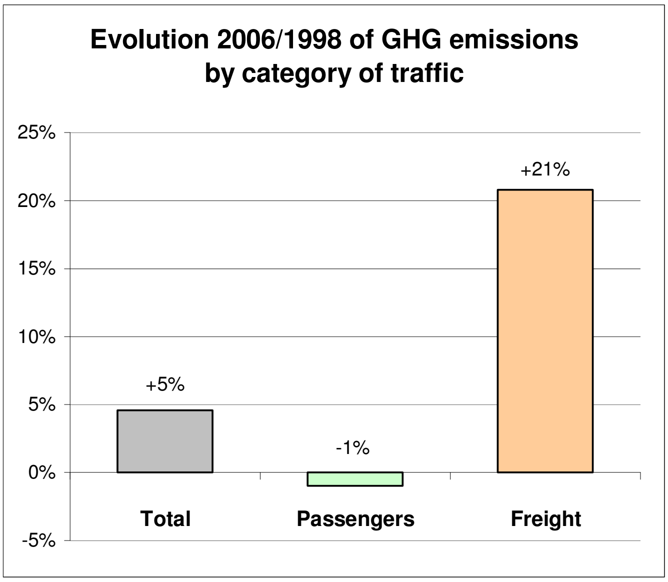
Freight transport participation to GHG emissions is considerable: it accounts for one third of the total emissions on the LMCU area.
But as regards the energy consumption related to transport we can note a relative stability over the period (+ 2 % between 1998 and 2006).




These results fit and confirm the trends observed at the national level: the share of emissions related to the transport in the total of GHG emissions at the national level for France was of 21 % in 1990 and has raised up to 26 % en 2006[14].

While GHG emissions are still rising, local pollutant emissions decrease substantially. The assessment for 2006 also shows that local air pollutant emissions, all types of pollutants included, have considerably decreased relatively to 1998: - 62 % for carbon monoxide, - 35 % for nitrogen oxides, - 56 % volatile organic components and - 36 % for fine particles.

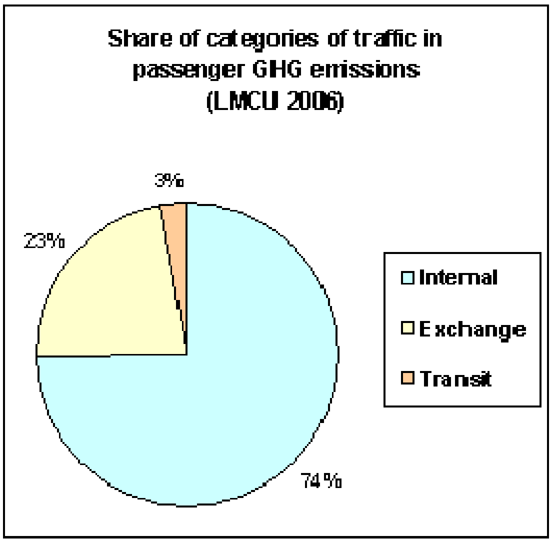
[13] Source : LMCU (Carbon Balance according to ADEME methdology)
[14] Source : *CITEPA, for Centre Interprofessionnel Technique d'Etudes de la Pollution atmosphérique*, in French. CITEPA is an inter-professional network in which relevant and up-to-date information about policy and technology on atmospheric pollution circulates

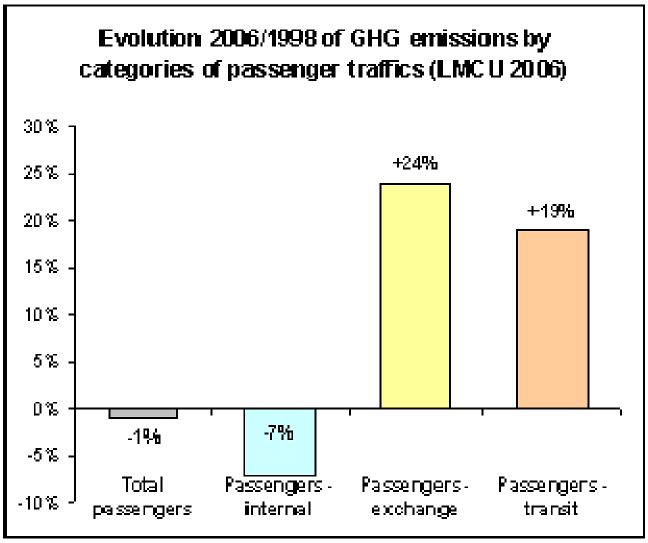



• **B/ Passengers and freight, contrasted evolutions over the period**

From 1998 to 2006, GHG emissions related to passenger trips are stable (- 1 %). On the contrary, those related to freight trips have strongly progressed (+ 21 %). The share of freight transport in the total of GHG emissions has gone from 25 % to 29 % between 1998 and 2006.

*• / Disparate situations according to individuals traffic types*
If the emissions of GHG in relation to passengers traffic are characterized by stability over the period (- 1 %), discrepancies exist between on the one hand the striking rise of emissions generated by passengers exchange and transit traffics (respectively + 24 % and + 19 %) and on the other hand the diminishing level (decrease) of emissions related to the internal trips (- 7 %).

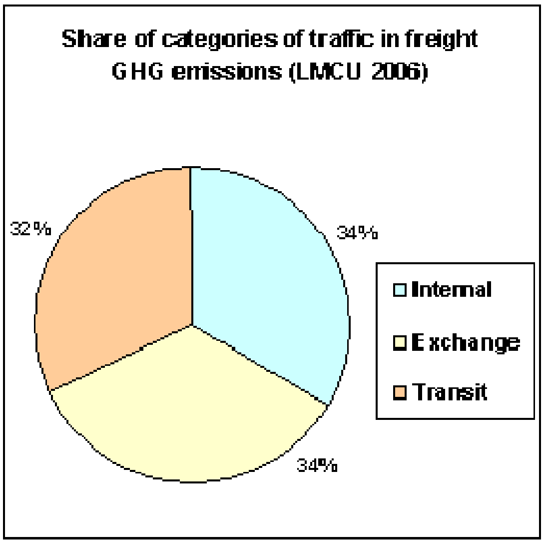


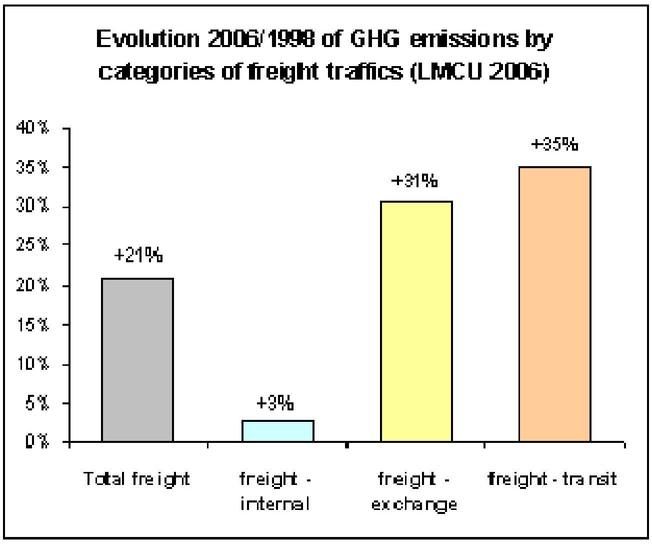




Stabilization of internal traffic allows benefiting from technological improvements of (passenger cars) engine. The greatly dominant share of internal flows among the totality of passenger transport (81 % in 1998 and 79 % in 2006) explains the stability of GHG emissions related to passenger trips.

**• C/ Freight transport growing strongly**

Freight traffic presents a very different structure compared to passengers one: in 2006, the composition of the traffic was of 8 % for transit, 30 % for exchange and only 12 % of internal flows related to urban logistics. All in all, freight traffic increased between 1998 and 2006, but transit and exchange increased the most: + 36 % for exchange *vs.* + 31 % for transit and only 3 % for internal traffic.




Energy consumption and GHG emissions are divided into three equal shares among the three types of freight traffics, in spite of the unequal distribution mentioned above. This is explained by the fact that one kilometer travelled on an urban way consumes more energy that one kilometer travelled on highway (partly due to a speed effect).

**• D/ Road modes remain mainly responsible for all polluting emissions**

Road traffic remains the main cause of air pollution and GHG emissions related to transport in urban areas.

For passengers as well as for freight, road mode is greatly prevailing among trips. Car (driver and passengers) accounts for 79 % of passenger flows (in passenger*km) in 2006, this share being slightly decreasing in comparison to 1998 (81 %). The contribution of car to polluting emissions is more important: car generates 95 % of GHG emissions, and from 91 % (volatile organic components) to 96 % (carbon monoxide) of local air pollutants related to the passengers' trips.

In the same way, 84 % of freight are brought by road in 2006 (flows in tons*km), and the share is increasing with respect to 1998 (82 %), generating 98 % CO2 emissions related to freight transport.

In addition, the strongest increases observed in traffics are occurring in road transport:
> Road traffics generated by exchange and transit trips of passengers with the Lille Urban Community have increased by + 30 % over the period;
> Road traffics generated by freight transport have increased by + 27 % in the same time.

## 4. Conclusion

The application developed here in the case of Lille urban area proves the feasibility of the MED methodology, upadating and extending the former methodology of EEAT we previously developed.

In order to assess the global contribution of transport to greenhouse effect (and climate change) (for example for environmetal assessments of "urban mobility plans"), a relevant evaluation should *a priori* consider all kinds of traffic and the complete length of the trips, including the part made outside the concerned area: precisely GHG emissions by transport activities is then twice higher than the ones identified by the MED. Thus, a particular care should be devoted to exchange trips and their relative environmental impacts.

Indeed this aspect should not to be neglected: the part of the exchange trips made outside the territory o Lille Urban Area. The MED methodology does not take into account the length of the exchange trips that is done only in the perimeter of the LMCU area. For example, considering exchange trips of passengers made by car, the MED only includes the 10.5 kilometers travelled on the Lille Community territory for the computation of the GHG and air pollutants emissions when the total length of the trip is of an average of 49 km.

The two dimensions of the issue of polluting air emissions makes essential and imperative to carry on different types of actions (political measures on urbanism and on transport sector) in order to get results and emissions reduction at the scale of Lille region but also in order to meet national and international commitments on climate change and nature preservation.

The strong decrease of the emissions of the local air pollutants should continue owing to more and more restrictives norms. However, the impacts of these norms will not fully matter before twenty years because of the complete renewal of the car fleet. Even if the 2006 level of emitted particles was over the 1987 level, the emissions should be reduced with the spreading of filter particls in the car fleet.

The situation is different when considering GHG emissions in relation to transport on the Lille Urban Community territory: computations show a rise by 45 % between 1990, based year for climate change policy goals, and 2006. Focusing only on the transport sector, reaching the target defined by these policies imposes to divide by 6 the GHG emissions compared to 2006 on the LMCU area.

The 4 factor of 1990 – a decrease by 75% of GHG emissions by 2050 – then becomes a 6 factor relatively to 2006. By 2020, the expected effects of the renewal of the ancient car fleet by new and less polluting cars should only allow to reach the 1990 level, under the assumption of a stabilization of all road traffics at their level of 2006.

Technical improvements would obviously not be enough to reach the aimed and desired decrease of GHG emissions of 20%-30% for 2020 for the transport sector and moreover the decrease by 75 % for 2050. Such a reduction can be reached only with strong political actions aiming to reduce car dependency by a better spatial organization of the activities on the territory and by promoting low carbon modes and public transit. The success of these policies relies on changing attitudes and travel behaviors, at the individual and the collective level towards an eco-friendly standing. Eco-mobility implies to change our way of thinking trips.

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